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Digital Signal Processing Applied in Mobile Communications

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ABSTRACT

Digital Signal Processing is an important software tool for several functions over digital signal, and Digital Signal Processors are microprocessors and microcontrollers specifically manufactured for the digital signal processing tasks. These DSP chips are used in everything from mobile phones to advanced scientific equipment including medical instruments. "DSP" mean for hardware as Digital Signal Processor or chip, software developers use to mean "DSP" as Digital Signal Processing. DSP has become a main functional component in communications, medical and industrial products. This paper describes the role of the Digital Signal Processing (DSP) in mobile communications from second to fifth generation. Mobile communications in present scenario (5G) advances a lot offering huge facilities like universal roaming with seamless connectivity, high data transfer rates, site service capabilities and support for high-quality multimedia services worldwide by using digital signal processing technique. In all steps of a mobile communications system, application of DSP is done for carrying out effective work. It is observed that digital signal processing becomes back bone to mobile communications from second to fifth generation and so on.

KEYWORDS: *Digital signal processing; Demodulation; Microcontrollers; Microprocessors; Mobile communication; Voice Signal*

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1. INTRODUCTION

Digital signal processing is an engineering software technique that focuses on analyzing, modifying and synthesizing signals, such as sound including voice or speech signals, images, potential fields, seismic signals, altimetry processing, and scientific measurements.

In hardware, DSP means microprocessor and microcontroller doing signal processing tasks and in algorithm or software, DSP indicates the program how to implement the tasks by the DSP chips or microprocessors. In this paper, DSP is meant for the application of digital signal processing tasks with the help of hardware chips and software programs both [1]-[4].

Now-a-days, digital communication becomes very much popular over analog communication due to following reasons:

A. Noise immunity, i.e., Ratio of Signal Power to Noise Power is high
B. Less interference and distortion
C. Real-time communication
D. Increased productivity
E. Enhanced tech skills and training
F. Increased knowledge or data sharing and innovation
G. An expanded talent pool
H. Increased employee retention

Digital signal processing is performed by different mathematical operations. Digital signal processors are microprocessors and microcontrollers specifically made for digital signal processing tasks. These devices have an enormous growth during the last decade, are used in everything from mobile phones to advanced scientific instruments.

In this paper, the application of digital signal processing in mobile communications field is enlightened and it is shown how DSP upgrades and boosts mobile communications in digital era.

2. Digital Signal Processing Characteristics

Natural signals such as human and animal's voice, audio, video, temperature, pressure etc. are aperiodic or non-periodic analog type, i.e., arbitrary changing their amplitudes with respect to time. Digital Signal Processors (DSP) take real-world analog signals like voice, audio, video, temperature, pressure, or position etc., those have been digitized, and then mathematically manipulate them. A DSP is designed for performing mathematical functions like 'add', 'subtract', 'multiply' and 'divide' very quickly. Fig. 1 shows the representation of an aperiodic natural analog signal in time domain and converting to digital domain by DSP.

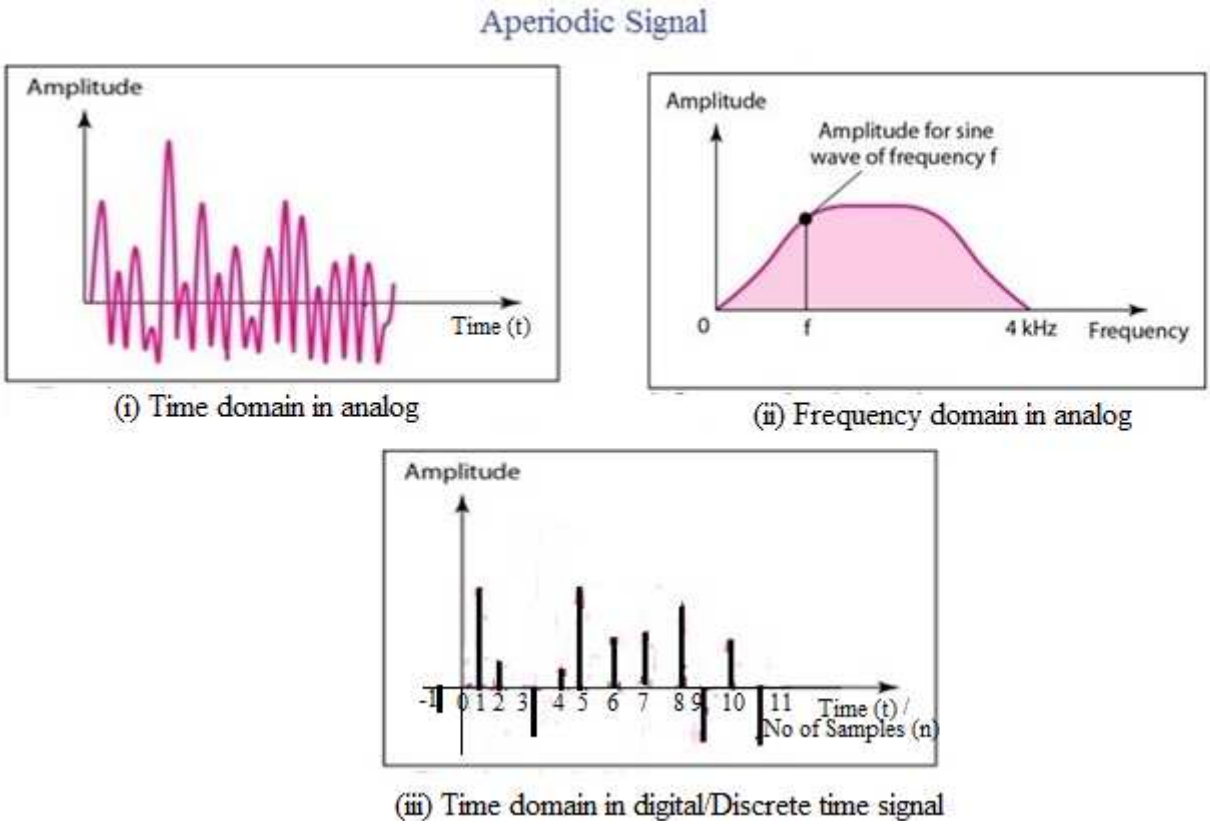

Fig. 1 An aperiodic signal represented in analog and digital form.

Digital signals can convey information with less noise, distortion and interference. Digital circuits can be reproduced easily in mass quantities at comparatively low costs. Digital signal processing is more flexible, because the operation of digital signal processor can be altered using digitally programmable systems.

Applications embedded digital signal processors are primarily used in consumer products such as radio, printers, mobile phones and mobile exchanges, fax/modems, disk drives, medical and health care devices, MP3 players, high-definition television (HDTV), and digital cameras [1]-[4].

DSP technology enables the processing and manipulation of sensory data obtained from a variety of real-world sources. Visual images, sound waves, and even seismic waves can all act as inputs for digital signal processing. The general function of a DSP is to measure, compress, or filter an analog signal.

Digital signal processing is done for the following tasks:

- Audio compression and signal processing.
- Data acquisition and signal processing.
- Digital image and graphics processing.
- Video compression and signal processing.
- Speech recognition and processing.
- RADAR, SONAR, and LiDAR signal processing and signal optimization.
- Seismic studies and data analysis.

Digital Signal Processor: DSP is a microprocessor and microcontroller specifically designed to process digital signals. Digital signal applications require real-time data processing over an input stream of digital values which is previously digitalized from an analog signal, i.e., voice signal. For mobile communications, it is the subscribers' voice signals. A DSP processor does mathematically operations on voice signals such as convert analog speech signal to digital form, different algebraic functions, speech signals analyzer, up sampling and down sampling of the digitalized speech signal, encoder and decoder, multiplexing and demultiplexing, digital modulation and demodulation of the speech signal, equalizer and filter for noise reduction system and signal restoration etc. In case of down sampling done for four samples, then one sample of the signal is taken out of four

consecutive signals, i.e., total number of samples are divided by four. On the contrary, if up sampling done for three samples, then total number of samples are increased by three times, i.e., multiplied by three. For up sampling, the amplitude of extra samples appended is generally taken as zero.

3. Application of Digital Signal Processing in Mobile Communications

A basic speech recognition algorithm can be split into three states like listening, processing, and matching. In the listening phase, the DSP analyses the present audio signal to determine if speech is present. When speech is detected, the DSP starts to process the information to describe the speech in a compact way.

The best example is that the processing of message signal through the BPSK modulation where it processes the message signal and embeds with the carrier signal and transmits it through the air. Any processing of signal is done by the system. In the above example, it is evident that the BPSK modulation is a system. In general system is defined as the physical device which is used to process any kind of signal. Modulators, Demodulators, Multiplexers, Encoder, De-multiplexer, Decoder, etc., are all examples of the system. In other words, system is defined as the unit comprised of several elements used to perform some task. That is, the system is to process a given input signal to produce the desired output.

The digital signal processor is the programmable device used to perform some operation on the input signal. Examples of such a processor are microprocessor and microcontroller. The outputs of the digital signal processor are also the digital signal. Finally the output digital signal from the processor unit is send to the digital to analog converter, which recovers the desired output analog signals from the digital output signals. In some situations, it is not necessary to convert the digital signal into analog signal. For example, in the RADAR processing, it estimates the information about the position and speed of the aircraft. In this case, the position and speed of the aircraft is displayed in the digital display, in which it does not require the conversion of the digital signal into analog signal.

1G mobile communication started at the time of Second World War, was based on analog communication. Also that time digital signal processing was not commenced in full swing. Later on 2G mobile communication begins commercially in 1975 as GSM (Global System for Mobile Communication) and CDMA (Code Division Multiple Access) use digital signal processing in signal transmission and receiving sides both. At transmitter, first of all analog voice signal is digitized, then the speech rate becomes 64 kbps/channel, this speech signal is down sampled to 16 kbps/channel to accommodate more number of channels within a certain bandwidth, i.e., four speech channel within 64 kbps. It is known that in mobile communication, very limited bandwidth or spectrum is offered in all over the world, e.g., for 2G and 3G mobile communications 800 MHz – 900 MHz or 1700 MHz – 1900 MHz. 4G and 5G mobile communications use spectrum 600 MHz – 700 MHz, 1700 MHz, 2100 MHz, 2300 MHz, 2500 MHz and 3300 MHz. Presently data rate is offered by 4G mobile communications 2 Mbps to 50 Mbps and 5G mobile communications 50 Mbps to 1 Gbps [5]-[9].

Mobile communications from 3G are totally based on packet switching technique dealt with various computer servers and each packet has specific length in byte, e.g., 53 byte/packet or 64 byte/packet etc. There are some bits allotted in each packet implemented for error checking and error correction purpose. Therefore, mobile communications become stable and reliable communications worldwide with good speech quality having very less error or noise by applying digital signal processing technique.

All natural signals having analog type such as voice signals are aperiodic (non-periodic) signal going on arbitrary sequence. Therefore, at the transmitter this analog aperiodic voice or speech signal is converted to digital aperiodic voice signal having speech rate 64 kbps according to Nyquist's sampling theorem by DSP processor. Then the digitized voice sample (64 kbps) is down sampled at the rate of 16 kbps/channel, i.e., four number of voice channels are incorporated in one 64 kbps band. Different encryption techniques like private and public key, hash function etc. are introduced on the down sampled speech to adopt security measure by DSP.

Thereafter, different digital modulation techniques such as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Gaussian Minimum Shift Keying (GMSK), Quadrature Phase Shift Keying (QPSK), Orthogonal Frequency Division Multiplexing (OFDM) or Orthogonal Frequency Division Multiple Access (OFDMA) etc. are applied.

At the receiver, the modulated signal is dealt with denoising by Low Noise Filter, demodulated, decryption, up sampled, digital to analog conversion by digital signal processing technique to retrieve the original base band or speech signal [5]-[9].

4. Conclusion

It is observed that digital signal processing is applied each and every stage of a mobile communications

system (2G to 5G) from transmitter (beginning) to receiver (end).

Actually at transmitter analog voice signal is converted to digital voice signal, then processed for different tasks at transmitter and receiver both, and finally at receiver the digital voice signal is transformed to analog voice signal by digital signal processing. Digital signal processing takes care and controls the mobile communications signal flow within the network. Therefore, mobile communications are successfully implemented throughout the world by the help of digital signal processing technique.

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